

BAY-DELTA OVERSIGHT
COUNCIL
DRAFT

**BRIEFING PAPER ON
DELTA LEVEE AND CHANNEL
MANAGEMENT ISSUES**

Bay-Delta Oversight Council

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INTRODUCTION

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INTRODUCTION

Briefing Materials on Delta Levee and Channel Management Issues

This briefing package is meant to provide basic information on to Delta levees, and channels. The three categories of issues presented are general structural integrity issues, issues relating to seismic stability, and levee and channel maintenance issues related to the Senate Bill 34 program.

Also included, is a representative spectrum of perspectives regarding these topics submitted by various affected agencies. Time constraints did not allow for canvassing all agencies and concerned public groups, however, we believe that the coverage provided does encompass a fairly comprehensive identification of the major issues.

The Executive Summary seeks to provide an overview of the material contained herein. It deserves emphasis, however, that the Summary should not be considered a substitute for the full text of the issue papers. Rather, it is meant to provide merely a snapshot of the major points raised since the characterization and flavor of the entire prepared pieces simply cannot be replicated in the Summary.

Perspective papers are reproduced as submitted. The BDOC staff has not attempted to edit, interpret or otherwise characterize the issues or concerns being raised. The Executive Summaries of the perspectives offered represent a sincere attempt to objectively highlight the key points raised. It is here acknowledged that, especially with regard to data, the summaries are cursory at best.

The first section of the package covers general levee stability issues. The second section of the package presents a summary of seismic stability issues relating to Delta levees. In the last section a summary is presented of issues and conflicting priorities which have surfaced during the SB-34 program. Also, included in this final section is a discussion of the innovative techniques which have been employed to address these conflicts in priorities between flood protection and fish and wildlife resources.

Following the discussion papers, prepared comments are included, representing particular perspectives and concerns relating to the levee issues as submitted by affected State, Federal and local agencies, as well as a cross-section of other experts in the field.

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

GENERAL DELTA LEVEE ISSUES

DELTA LEVEE SEISMIC STABILITY ISSUES

INTRODUCTION

Without levees, the Delta, as we know it, would not exist. Delta levees serve many functions, from serving as wildlife habitat and protecting wildlife habitat on the islands, to playing an important role in maintaining Delta water quality and, of course, providing flood protection. Levees, and the channels maintained by them, are also critical to the Delta's role as the hub of the state's water transfer system.

Reclamation of the Delta began in the 1800s. Since that time, the height of Delta levees, relative to land side elevations, has increased from about five to twenty-five feet, generally because of subsidence of the islands. Many of the Delta's levees were built in a piecemeal fashion over several decades. In most cases, they were engineered without the benefit of modern scientific knowledge of geology, hydrology, geophysics or subsidence (the lowering of peat island interior land levels as a result of soil erosion and microbial decomposition accelerated by agricultural activity). Consequently, there has been and continues to be uncertainty about their ability to continue to protect Delta resources.

As a consequence of subsidence, land elevations in the Delta are, for the most part, much lower than waterway elevations. This requires that Delta levees act as water barriers at all times, complicating their repair and maintenance.

With respect to the subsidence problem, it is important to note the distinction between areas where peat soils underlie islands and those where mineral soils do. Generally, those islands composed of mineral soils do not suffer from a significant subsidence problem. However, the peat soil islands are subject to the lowering of land levels through subsidence, caused by microbial decomposition of the peat soils as they are exposed to the air. Those islands most affected by subsidence and thus with the lower interior levels and greater levee heights are located in the central and western Delta, while mineral islands tend to be found around the Delta perimeter with higher interior land levels, including some which are above sea level.

The Delta Flood Protection Act of 1988 (SB-34) sought to provide a focus for coordinated engineering investigations and improvement projects for non-project levees, with regard to overall design, maintenance, and protection of environmental values. SB-34's funding level of \$12 million per year, however, is less than that necessary to properly upgrade all Delta levees that require strengthening. The U.S. Army Corps of Engineers

(Corps) in 1982 estimated that it would cost \$1 billion to rehabilitate levees on 53 Delta islands. However, recent non-project levee improvements have been made at costs that indicate this figure could be decreased by 25% or more through the use of innovative engineering techniques. While many individuals involved in the SB-34 program believe that a comprehensive cost sharing plan needs to be implemented that will include all beneficiaries of levee protection, others are wary of too much centralization.

SB-34 also funds mitigation programs. To date, over \$3 million has been provided to the Department of Fish and Game (DFG) to mitigate impacts to habitat. However, controversy over implementation and management of SB-34 programs meant to supplement local projects to improve levee conditions has stymied efforts to move forward as expeditiously as many would like. Discussions are ongoing to resolve areas of contention between state agencies and local reclamation districts.

HISTORY OF DELTA LEVEES

Delta reclamation began in the early 1850s. In 1861 the State passed the Reclamation District Act and in 1868 turned over responsibility for reclamation to local agencies and landowners.

Hydraulic mining during this era (halted by court decree in 1884) exacerbated Delta flood control problems as the debris washed down out of the mountains and reduced channel capacity. Also exacerbating this situation was the fact that as the Delta became more channelized and flood plains were protected, flood stages rose, necessitating still higher levees.

In 1893, the Corps was given federal jurisdiction over flood control. Today, the Corps manages a comprehensive program, the Sacramento River Flood Control Project (SRFCP), which focuses on levee improvement and maintenance.

The Corps is responsible for "project levees" constructed as part of the SRFCP, located mostly along the Sacramento and San Joaquin rivers and maintained to relatively high Corps standards. Nonproject levees (which comprise about 75% of all Delta levees) were constructed piecemeal by land owners and local reclamation districts and are maintained to varying degrees, although generally to a lower standard than those maintained by the Corps.

Flooding in each year from 1980 through 1983 and again in 1986 illustrated the vulnerability of nonproject levees and caused an estimated \$100 million in damage to the levee system, of which \$65 million was paid for by the Federal Emergency Management Agency (FEMA).

As a condition of future disaster relief, FEMA has imposed a minimum standard requirement for improvement of nonproject levees. This standard is contained in the state's

Hazard Mitigation Plan (HMP), prepared in 1983 and updated in 1986.

The state's primary responsibilities under the HMP are providing continued financial assistance to local reclamation districts (this was done through SB-34) and carrying out an annual inspection program. As indicated above, under the HMP local districts had to upgrade their levees to a specified standard. These improvements were scheduled to be completed by September 1991. As of November 1991, however, although most districts have made some progress toward satisfying the HMP, only four of forty-seven inspected districts complied with the minimum criteria.

Local reclamation districts point to delays in receiving state and federal disaster relief, as well as DFG policy requiring stream bed alteration agreements for work performed on the waterside of nonproject levees, as obstacles to meeting implementation schedules. An agreement is in process to allow a time extension in the HMP so that FEMA can evaluate progress on a district-by-district basis.

A key contributor to levee problems in non-mineral soil areas is subsidence, the lowering of the interior land level primarily as a consequence of microbial decomposition, topsoil erosion and oxidation of the islands' peat soils. Subsidence in the Delta has historically occurred at rates that are among the highest in the world. Levees which were originally built 2 or 3 feet above ground elevation, must now be maintained, in many cases, at heights of over 20 feet above the adjacent ground as a result of interior island subsidence.

Peat soil under levee foundations, subsidence and the use of sand in the construction of levees, are the primary factors that contribute to levee instability today.

BENEFITS DELTA LEVEES PROTECT

Levees not only provide direct flood control protection for Delta lands and highways, railroads, natural gas fields, utilities, major aqueducts, homes and marinas, but they also provide indirect benefits to wildlife, Delta agriculture, water quality and recreation.

If the levees were not maintained and islands were allowed to flood, there would be a significant loss of habitat for land based wildlife species, including important wintering waterfowl habitat. This loss would create marginal habitat for aquatic species which would then inhabit the flooded islands.

Levees also provide riparian habitat for wildlife. While problematic for inspection and maintenance of the levees, riparian vegetation contributes to the shading of near shore (i.e. near levee) areas which are important habitat areas within the Estuary ecosystem.

Without the levees, Delta islands would not exist and obviously could not be cultivated. This would be a loss of over a half-million acres of agricultural lands and a half-

billion dollars of annual gross income from agricultural and related activities. Also, channels between tracts and maintained by the levees provide farmers with access to a ready source of irrigation water for their crops.

By maintaining the integrity of Delta channels, levees serve to protect the flow of water from the north of the Delta to the south and toward the pumps of the federal Central Valley Project and State Water Project. The present water transfer capacity of the Delta to move water is not as good as it might be, but it is generally considered to be better than if there were no levees at all.

Western Delta islands serve as "barriers" that help stem the tide of salt water intrusion into the interior Delta. This is important for maintaining adequate water quality for beneficial uses served by the Delta, including fishery resources, recreation, in-Delta agricultural use and the quality of water exports among others.

The Delta is one of California's major recreational areas. It not only serves local and regional residents but it is also a recreational destination for boaters from throughout California. The Delta's 50,000 acres of meandering and interwoven waterways serve over 12 million recreational user days annually. Recreational uses include fishing, water sports, houseboating, hunting, etc.

DELTA LEVEE FAILURE MECHANISMS

Levee failures can be categorized principally by the major type of failure (stability, overtopping, seepage/erosion) and then by contributing factors (cracks/fractures, encroachments, deformation, sink holes, burrows, poor foundations). Subsidence, of the island interior and the levee itself, is another factor that must always be addressed when seeking to maintain levee stability. Seismic activity is also considered to be a probable failure mechanism. However, there is still only minimal understanding of how seismic events actually affect levee stability and what the impacts of a major quake would be.

Subsidence

Subsidence, or lowering of the land surface, results primarily from peat soil being converted into a gas. Many Delta islands are composed of peat soils which decompose when exposed to oxygen and higher temperatures, a circumstance that is accelerated by agricultural activity. Mineral soils underlie the southern and eastern islands of the Delta and so they are not subject to the severe subsidence problems of the islands composed of peat soils. Another type of subsidence can occur when groundwater or natural gas is withdrawn. This so-called "deep" subsidence has little significance compared to "shallow" subsidence associated with soil erosion and oxidation. Controlling subsidence should be a significant element of any Delta flood

control plan.

Stability

Factors affecting stability include size, shape, composition of foundation materials, strength, deformability and water pressure. While east Delta levees are generally supported by foundation materials composed of clay, silt, and sand, western Delta levees are primarily resting on peat with some alluvial clay, bay mud, sand and silt. While inorganic materials provide adequate foundations, uncompressed peat is highly deformable and unstable.

Overtopping

Overtopping failure occurs when the crest of a levee is lower than the water level. Overtopping can occur not only as a result of the presence of flood flows, but also as a consequence of high tides and wind. Overtopping is of particular concern in the north and west Delta.

Subsurface Seepage Erosion

Water seeping through or beneath levees contributes to erosion problems and a levee subject to such seepage may wash away from the inside out. Sandy levees are especially susceptible to seepage erosion and the resulting formation of "pipes" (large voids). Uncontrolled vegetation on levees can cause and shield piping from prompt discovery.

Seismic Activity

Although preliminary studies have been completed in recent years, they have been inconclusive because of the lack of information regarding levees and their foundations, and uncertainty about the capabilities of organic soils beneath the levees to either amplify or attenuate ground motions triggered by earthquakes. Still, because levees are comprised of uncompacted sands, silts, clays, and organic soils, there is concern that they would be susceptible to liquefaction and damage during moderate to strong earthquake shaking.

FAILURE MODES

Cracks and Fractures

This mode is a particular problem for deformable levees built upon peaty foundations, as cracking will occur at load levels significantly below those required to cause a complete stability failure. While cracks do pose a stability problem, they pose a greater danger by providing shorter, unobstructed pathways for piping to occur.

Encroachments

Encroachment of structures onto levee slopes may reduce the level of protection provided by the levee system and also make levee inspection, maintenance and improvements more difficult. Bethel Island and Hotchkiss Tract have many encroaching structures which were built before a setback regulation was adopted in 1989. Encroachment control plans are currently under development on other islands.

Erosion

Levee waterside slopes are subject to varying erosional effects from channel flows, tidal action (which can cause water levels in some channels to vary by as much as 4 feet daily), wind-generated waves, and boat wakes. To counter erosion, riprap (rock) may be placed on the levee or a berm may be placed as a buffer in front of the levee to dissipate the water-borne energy before it reaches the levee itself.

Although vegetation can contribute to piping problems, it is generally desirable as a tool in controlling erosion. However, continual wave action at normal water levels frequently undercuts vegetation at the waterline, and can lead to progressive caving and erosion of the levee slope.

Deformation

Levee foundations composed of peat or other soft organic soils are analogous to toothpaste. If enough pressure is placed upon them, the soils may squeeze out as they migrate to the path of least resistance. Placing heavy berms at the land side toe of the levee has been an effective method of "capping" the soft soils and preventing deformation.

Seepage

Because interior land levels in many areas are so far below channel water levels outside the levees, seepage is a continual problem that contributes to instability in the low lying islands of the central and western Delta.

Sinkholes

Sinkholes are depressions in the land side of the levee that are typically wet or filled with water. These sinkholes are symptomatic of erosion problems, specifically piping and deformation, and are usually found near levees overlying peat soils. Surface filling is the most effective corrective measure to mend sinkholes.

Rodent Burrows

Rodent burrows increase the potential for piping problems to develop. Often, dense vegetation on levee slopes makes it difficult and impractical (but not impossible) to detect burrows.

LEEVE DESIGN

Levee conditions in the Delta are unique in that unlike most locations where levees are built to protect land which is at a level above normal water levels, Delta levees protect lands which are far below the water level. Consequently, while levees in other regions generally need to be able to sustain pressures on an intermittent basis, Delta levees are really earthen dams which must function as continuous water barriers. Thus, Delta levees must remain fully functional during any improvements or repairs.

There are six main components of levee design: levee material, levee height, slope and foundation stability, seepage control, deformation control and erosion control.

LEEVE MATERIAL

The Corps recently determined that it would take approximately 55 million cubic yards of material to rehabilitate substandard Delta levees. Because of the general scarcity of suitable soils within the Delta, most of that material would have to be imported.

The most accessible source of fill material is dredge spoils and sediment from Delta channels. However, removing material from the waterside toe of levees can cause stability and seepage problems. In addition, it is becoming increasingly difficult to remove channel material as a consequence of federal and state endangered species act restrictions on dredging operations.

Another potential source of levee fill material is land that may be borrowed when creating new wildlife habitat areas. For example, habitat plans under development for 500 acres of Department of Water Resources (DWR) land in the north Delta may provide several hundred thousand cubic yards of material.

Sand deposits on some islands are also a source of fill material.

Long-Term Management Strategy (LTMS)

The LTMS is a program to prepare plans to manage dredging and the disposal of dredge spoils from the Bay over the next 50 years. The key participants in the program are the Corps, the U.S. Environmental Protection Agency, the San Francisco Regional Water Quality Control Board (SFRWQCB), and the San Francisco Bay Conservation and Development Commission.

Dredging in the Bay creates an annual disposal requirement of approximately 8 million cubic yards of material.

While some have suggested using those spoils to upgrade Delta levees, there are significant concerns regarding the possibility of water quality impacts (both salinity and pollutants). DWR, working with the Corps and the SFRWQCB, has been conducting demonstration projects to determine the viability of using Bay dredge material on Delta levees. In 1990, 1,600 cubic yards of dredge sediments from Suisun Slough was used to build a land side berm. After two years of monitoring, no adverse impact was detected on soils or water quality. In 1992, 50,000 CYs of sandy material from Suisun Bay was placed on Twitchell Island. Monitoring has not identified any significant salinity impacts.

LEVEE FUNDING

In conjunction with funds from local landowners and reclamation districts, the Federal Emergency Management Agency (FEMA) has provided significant revenues for rehabilitation of levees after breaches have occurred.

Today, non-project levee enhancement is funded through the Delta Flood Protection Act of 1988 (SB-34). SB-34 authorized \$12 million annually through 1998-99, with the money to be split between supplementing local revenues and funding special levee projects in the western Delta and flood protection for Walnut Grove and Thornton. Appropriations to the SB-34 programs in the past two years have been substantially less than the authorized \$12 million per year, although the intended \$12 million was provided this year.

The cost of rehabilitating or raising the level of protection of a levee ranges from \$1.5 million to \$4 million a mile, depending upon the condition of the levee and its location. Because local landowners and reclamation districts cannot raise sufficient funds themselves, and SB-34 monies are also not of the magnitude needed to alleviate the entire problem, many people knowledgeable in Delta levee issues believe that a comprehensive cost sharing

arrangement amongst all benefiting parties needs to be established to equitably satisfy their needs. Others, however, do not wish to see a centralized system with such control over what is seen as a local issue.

COMMENTS AND PERSPECTIVES OF PEER REVIEWERS

Reclamation District #548 in Lodi offered some recommendations: (1) long term cost sharing arrangements extending beyond the year 2000 should be implemented by the Legislature; (2) the Legislature should create an emergency fund; (3) the Legislature should set a 5 mph boat speed limit in specified areas of the Delta; and, (4) State agencies should implement plans to preserve channel islands and enhance habitat on them. A concern was also raised that without State and/or federal assistance, levees protecting small islands will not be repaired as local residents cannot afford to do so on their own. The proposed emergency fund would be in place for this purpose.

The California Central Valley Flood Control Association cautioned that comparisons of 1982 Corps estimates of levee repair costs to costs associated with recent levee repair work might be misleading as the Corps' estimates included recreation and fish and wildlife enhancement in addition to basic structural rehabilitation.

The State Reclamation Board (Board) commented that it is responsible under agreements with the Corps for operation and maintenance of Project levees. There are currently about 17 miles of federal levees within the Delta which are in need of repair. The Board, the Corps, and affected reclamation districts will be cost-sharing efforts to repair these levees.

The Seismic Safety Commission cautioned against interpreting the briefing paper as implying that earthquakes are not a concern as there is evidence that seismic activity does impact the integrity of the levees even though, historically, catastrophic failure has not been attributed to seismic events.

The Corps commented that it is important to distinguish between environmental mitigation and outright habitat creation. Additionally, the Corps notes that a great deal of work has been done to improve Delta levees since 1982.

Reclamation District #2026, managing Webb Tract, commented that the briefing paper may give an overly pessimistic impression in that far less than half of the 550,000+ acres in the Delta which are protected by levees is threatened by significant soft soil problems and subsidence. The majority of the islands are composed of mineral soils and as such are not subject to the same degree of levee problems as those in peat soil areas. Moreover, the District believes that management practices in the entire Delta need not be developed on the worst-case basis.

The East Bay Municipal Utility District (EBMUD) suggested that liquefaction from seismic forces be added to the list of levee failure mechanisms. Also, EBMUD emphasized that three of EBMUD's Mokelumne Aqueduct pipelines cross the Delta in areas which make them vulnerable to damage from levee failures caused by seismic activity or flooding. EBMUD also communicated that it has just completed an Aqueduct Security Study and has begun an Aqueduct Upgrade Project.

The Delta Protection Commission's Executive Director highlighted the apparent conflict between protecting the habitat value of the levees and the inspection, maintenance and rehabilitation problems associated with wildlife and vegetation.

The Central Delta Water Agency commented that levee alignment issues need to be better understood. Also, it needed to be noted that significant funding provided by the State's Natural Disaster Assistance Act (over \$26 million from 1980-1986) for emergency levee repair was critical to receiving \$65 million in FEMA assistance.

DELTA LEVEE REPAIR AND MAINTENANCE ISSUES

INTRODUCTION

With respect to levee and channel maintenance in the Delta, there are inherent conflicts between retaining and restoring fish and wildlife habitat on levees and maintaining those levees for flood protection. Implementation of the Delta Flood Protection Act of 1988 (SB-34) has been at the center of this debate. Included in this briefing report is a paper describing some of the issues pertaining to SB-34 programs, along with an appendix reviewing some of the fish and wildlife values associated with and protected by the Delta's levee and channel system.

Although the SB-34 discussion focuses mainly on "non-project" levees, some of the concerns raised are similarly applicable to "project" levees.

Non-project levees are maintained, repaired and upgraded by local reclamation districts in accordance with the State's Flood Hazard Mitigation Plan (FHMP) for the Delta. Portions of the costs for implementation of the FHMP are potentially reimbursable through the SB-34 program (up to 75% for maintenance and rehabilitation and up to 100% for habitat mitigation work). Project levees are maintained according to federal regulatory standards.

Traditionally, levees were considered almost exclusively as a means to protect farm land, homes, and other public development including railroads and highways. In addition to those considerations, fish and wildlife habitat issues have in recent years received increased importance. With this shift a conflict among uses and purposes has arisen, as maintaining and developing habitat values on the levees is believed by many to threaten the levees' structural integrity or, at minimum, impair routine inspection, maintenance and repair. Still, despite disagreement among the players over emphasis and priorities, there is general agreement as to the benefits of protecting Delta islands and their important habitat values.

LEVEE AND CHANNEL MAINTENANCE ISSUES

Dredging may result in temporary adverse water quality impacts, which can also affect aquatic resources in the impacted area. These concerns, particularly with respect to enforcement of the federal Endangered Species Act have limited dredging activities in the Delta to a 60 day period in the summer when fishery impacts are minimized. As long as the dredging window is so restricted, there is a risk that fill material from dredging will not be available to maintain and restore levees.

LEEVE MAINTENANCE ACTIVITIES

Installation of revetments and riprap typically requires removal of vegetation which often results in conflicts with maintenance of both aquatic and terrestrial habitat. Many levee maintenance managers believe that extensive vegetation on the levees can present a hazard to flood protection capabilities. Fish and wildlife managers emphasize the importance of maintaining levee vegetation for habitat values. The perception of the impacts, both to wildlife and habitat and to the levees, tends to differ, depending on the focus or responsibility of the individual or agency. As expected, agencies responsible for flood protection place a higher priority on that issue while fish and wildlife agencies place a higher priority on their responsibility to maintain fish and wildlife resources. In addition to the difference of opinion as to the nature of the problem, there are also disagreements over the appropriate maintenance methods.

CURRENT INITIATIVES TO ADDRESS THE LEEVE CONCERNS

Programs are currently underway at the State and local level to address the need to protect habitat values while maintaining flood protection. Such programs include levee maintenance and some dredging activities.

Vegetation guidelines are being developed for levee habitat enhancement and mitigation.

Also, two demonstration slope protection projects have been implemented as part of the SB-34 program using materials other than riprap which allow vegetation regrowth without erosion. Many districts feel these relatively expensive alternatives are unnecessary as they believe that riparian vegetation can effectively reestablish itself on riprap.

Fish exclusion devices are being studied for use at sites where clamshell dredging is occurring. Also, fish distribution studies are underway to try to assess where dredging might take place at other times of the year without harm to aquatic species of concern.

INTERAGENCY COORDINATION

There exists a Delta Levee and Habitat Advisory Committee within the Resources Agency that is working to (1) Streamline permits for levee work in the Delta; (2) Explore the utility of Habitat Conservation Plans; and (3) Provide guidance on Habitat Mitigation Plans. The Resources Agency has also had recent discussions with the Corps and the USFWS to secure a General Permit for SB-34 projects.

The California Department of Fish and Game will soon release its "Mitigation Guidance Document," which is a handbook for levee districts and landowners to assist in the

development of habitat mitigation plans. One of the key proposals endorsed is the use of mitigation "banks" to enhance overall habitat quality and diversity.

ISSUES AND IMPLEMENTATION OF THE SB-34 PROGRAM

SB-34 was enacted to facilitate and fund levee maintenance, with specific emphasis on New Hope Tract and eight key west Delta islands. SB-34 also focused on protecting and enhancing the fish, plant and wildlife resources of the Delta. Most significantly, SB-34 required that projects receiving funding arising from the Act would not result in a net long-term loss of riparian, fisheries or wildlife habitat, with a DFG finding to that effect to be issued before funds are disbursed.

Initially, there were disputes around regulatory jurisdictional issues and also differences of opinion concerning the intent of the legislation. Follow-up legislation, SB-1065, provided specific guidance and consequently the reclamation districts, assisted by DWR and DFG have made progress towards meeting the habitat conservation goals originally set forth in SB-34.

While resolution of the conflict between competing priorities of flood protection and habitat protection have held center stage, funding is a growing concern. Although originally set at \$12 million per year through 1997, funding was less than that in 1991-92 and was only \$2 million in 1992-93. Additionally, \$3 million specifically set aside for DFG mitigation programs has not been expended and the monies will revert to the general fund on June 30, 1994. There is some concern that this funding opportunity will be lost because an acceptable project cannot be decided upon.

Without additional legislation, SB-34 funding authorizations will expire in 1997 and full funding for levee maintenance will revert back to local reclamation districts.

CONCLUSION

Though plagued by early conflicts between flood protection and habitat values, recent history suggests that the SB-34 program is becoming more effective. Continued focus on minimizing environmental impacts while developing innovative techniques to restore and maintain the structural integrity of the levees remains the key to successful programs.